GROUNDWATER RECHARGE AND SOLUTE MIGRATION IN A FRACTURED CHALK AQUITARD

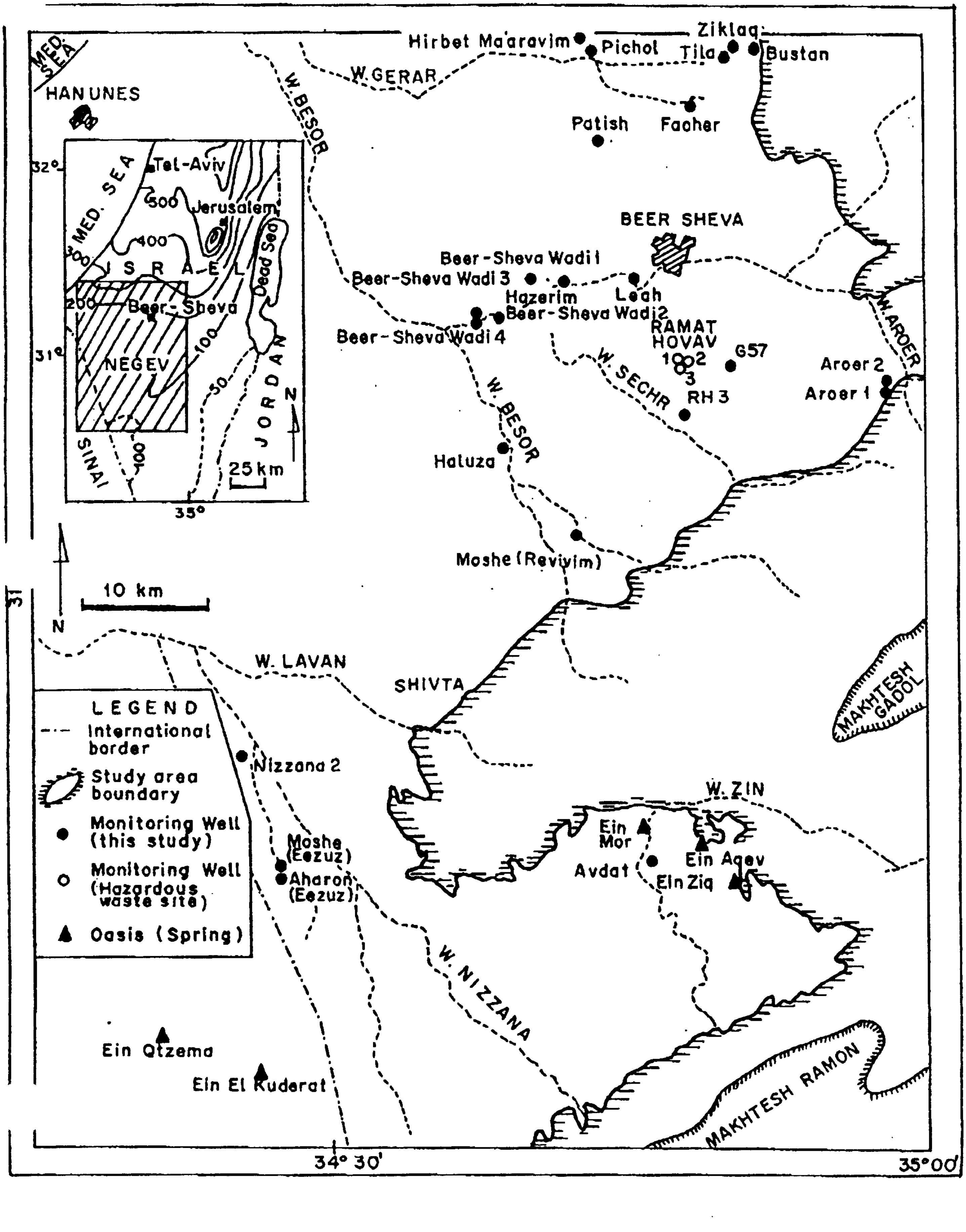
Ronit Nativ

Eilon Adar

Ofer Dahan

Ilan Nissim

Mebus Geyh



MED. SEA
HANUNES
Hirbet Ma'aravim
Pichol
Ziklaq
Tila
Bustan
W. GERAR
W. BESOR
Patish
Faaher
BEER SHEVA
Beer-Sheva Wadi 1
Beer-Sheva Wadi 3
Hazerim
Leah
Beer-Sheva Wadi 2
Beer-Sheva Wadi 4
RAMAT HOVAV
G57
Aroer 2
Aroer 1
W. AROER
W. SECHR
RH 3
Haluza
Moshe (Revivim)
10 km
N
W. LAVAN
SHIVTA
MAKHTESH GADOL
Nizzana 2
W. ZIN
Ein Mor
Avdat
Ein Aqev
Ein Ziq
Moshe (Eezuz)
Aharon (Eezuz)
W. NIZZANA
Ein Qtzema
Ein El Kuderat
MAKHTESH RAMON
34° 30'
35°00'
31
32°
31°
35°
Tel-Aviv
Jerusalem
MED. SEA
ISRAEL
Beer-Sheva
NEGEV
SINAI
Dead Sea
JORDAN
500
400
300
200
100
50
25 km
LEGEND
International border
Study area boundary
Monitoring Well (this study)
Monitoring Well (Hazardous waste site)
Oasis (Spring)

REGIONAL GROUNDWATER FLOW IN A CHALK AQUITARD, NEGEV, ISRAEL

Observations

(1) Abundance of fissures, joints and fractures

(2) Secondary mineralization in fractures

(3) Seasonal fluctuations in water level

(4) Abundance of tritium in groundwater

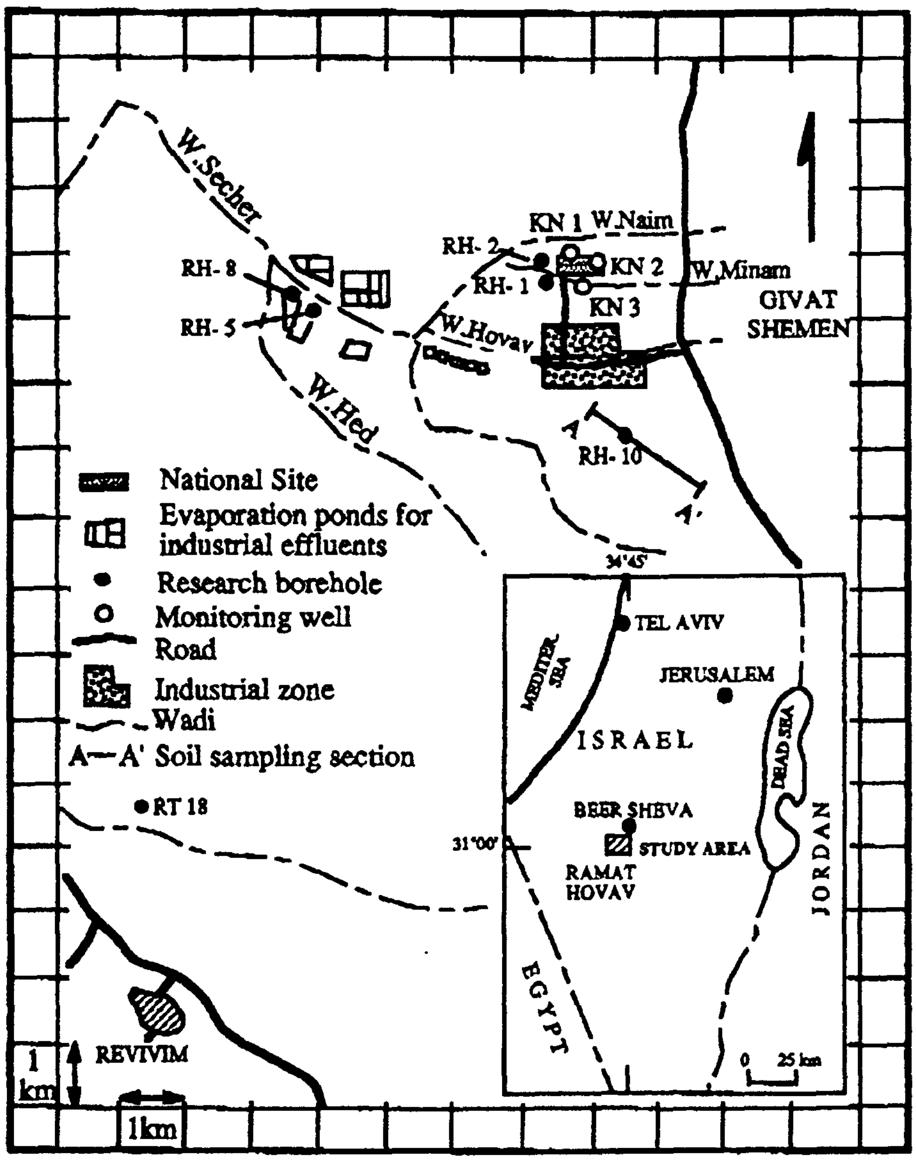
(5) Rapid (within a decade) contamination of groundwater

(6) Similarity in the stable isotopic composition of groundwater and precipitation

REGIONAL GROUNDWATER FLOW IN A CHALK AQUITARD, NEGEV, ISRAEL

Conclusion

Water and solutes shortcut through the low-permeability matrix via fractures and joints, escaping evaporation.



W.Secher
KN 1 W.Naim
RH- 2
KN 2
W.Minam
RH- 1
KN 3
GIVAT SHEMEN
RH- 8
RH- 5
W.Hovav
W.Hed
A
RH- 10
A'
National Site
Evaporation ponds for industrial effluents
Research borehole
Monitoring well
Road
Industrial zone
Wadi
A—A' Soil sampling section
RT 18
REVIVIM
1 km
1km
34°45'
TEL AVIV
MEDITER. SEA
JERUSALEM
ISRAEL
DEAD SEA
BEER SHEVA
31°00'
STUDY AREA
RAMAT HOVAV
JORDAN
EGYPT
0 25 km

GROUNDWATER FLOW IN THE VADOSE CHALK, NEGEV, ISRAEL

Methods

(1) Cored rock samples for:

- Tritium profiles to estimate water-percolation rates
- Chloride profiles to assess nonreactive solute transport
- Bromide profiles to evaluate nonreactive contaminant transport
- Deuterium and oxygen-18 profiles to assess evaporation

(2) Observed vertical fracture distribution in cores

GROUNDWATER FLOW IN THE VADOSE CHALK, NEGEV, ISRAEL

Observations

(1) Near-saturation water content in the vadose chalk

(2) Low permeability of the chalk matrix (2 millidarcy)

(3) Presence of tritium spikes below the tritium front

(4) Vertical deplition of stable isotopes

(5) Vetical dilution of salts

(6) Mineralization

Conclusions

(1) Water entering the fractures is not immediately imbibed by the matrix. Instead:

(2) Water wets the fracture walls and rapidly percolates through major conduits.

GROUNDWATER FLOW IN THE VADOSE CHALK, NEGEV, ISRAEL

Observations

(1) Near-saturation water content in the vadose chalk

(2) Low permeability of the chalk matrix (2 millidarcy)

(3) Presence of tritium spikes below the tritium front

(4) Vertical deplition of stable isotopes

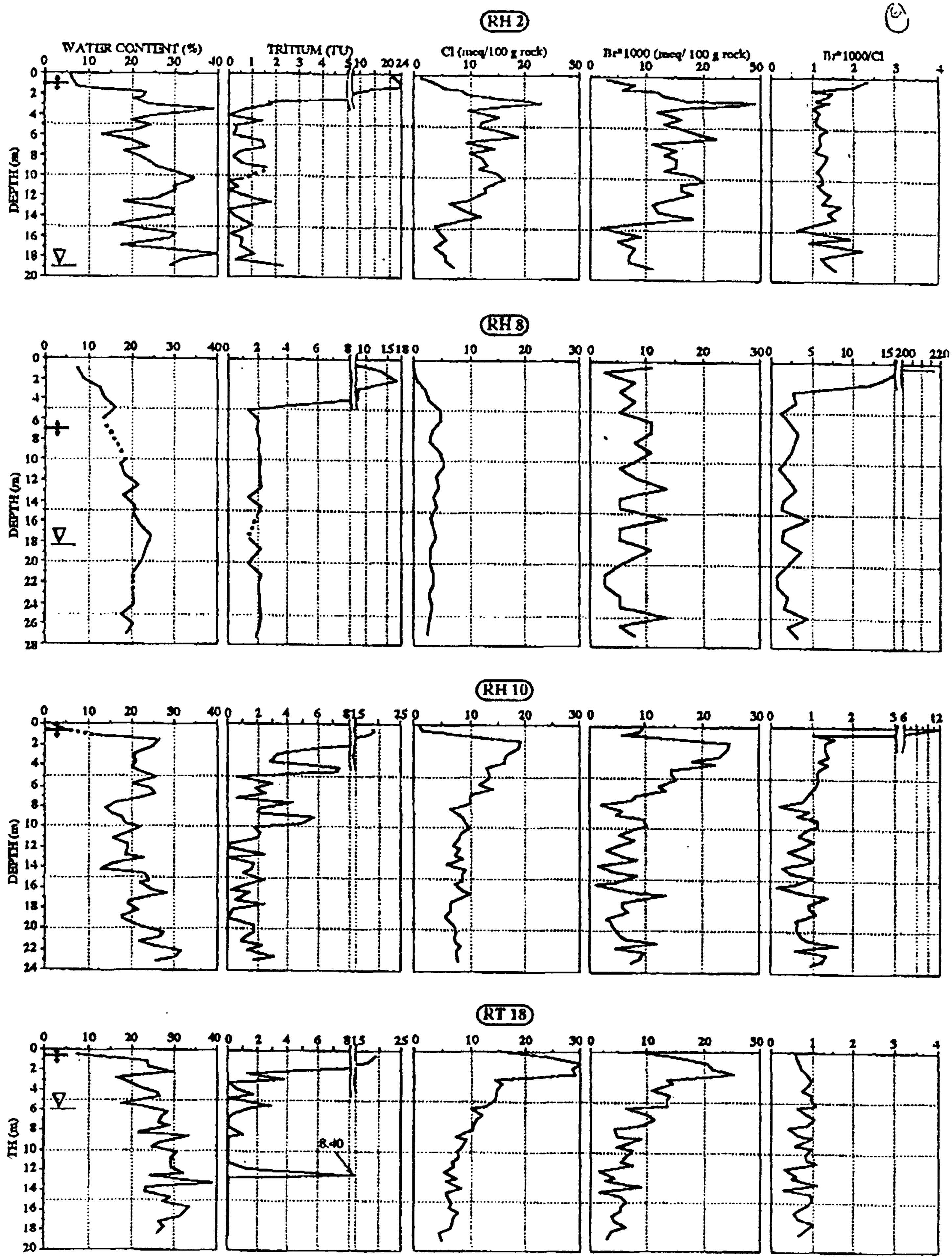
(5) Vetical dilution of salts

(6) Mineralization

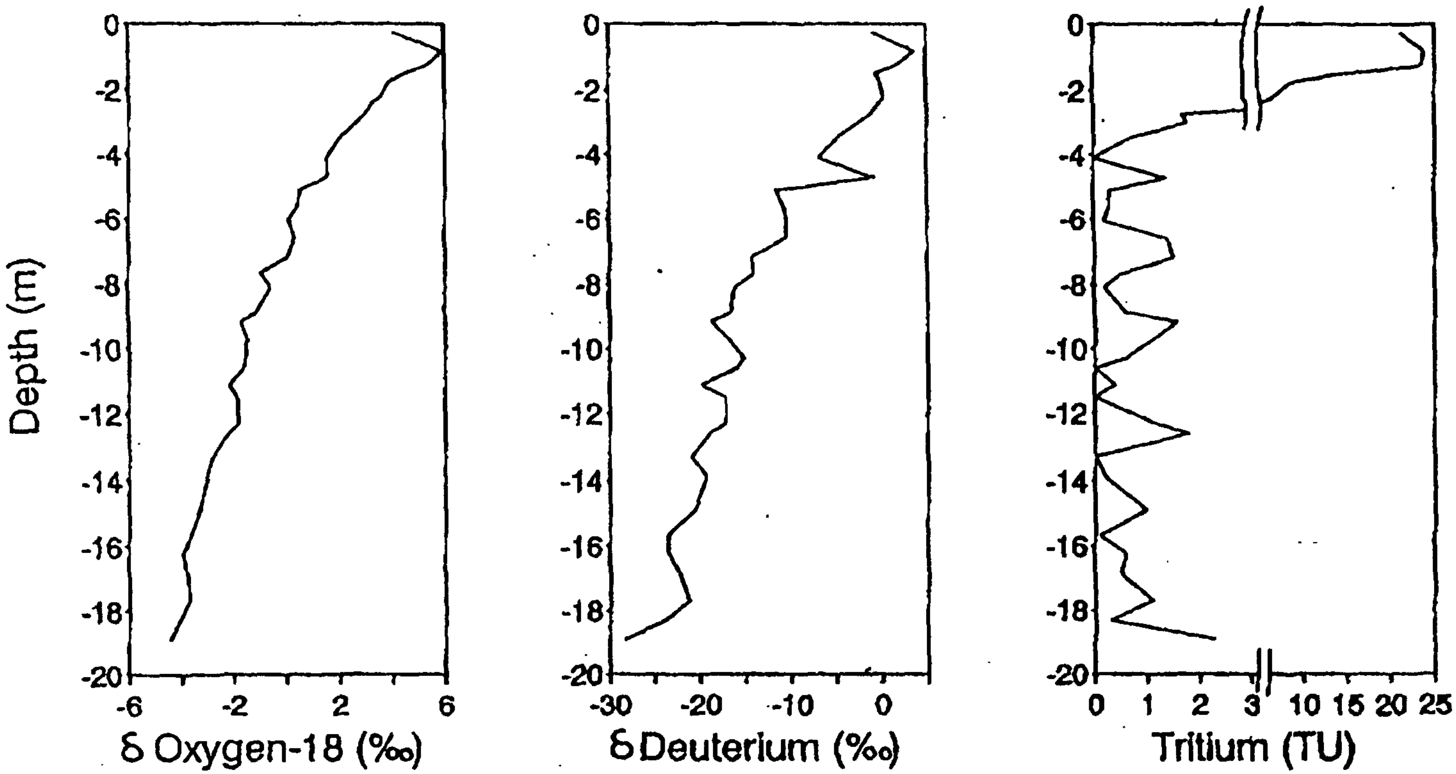
Conclusions

(1) Water entering the fractures is not immediately imbibed by the matrix. Instead:

(2) Water wets the fracture walls and rapidly percolates through major conduits.



RH 2
WATER CONTENT (%)
TRITIUM (TU)
Cl (meq/100 g rock)
Br*1000 (meq/ 100 g rock)
Br*1000/Cl
DEPTH (m)
RH 8
RH 10
8.40
RT 18
TH (m)



Depth (m)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-6
-2
2
6
δ Oxygen-18 (‰)
-30
-20
-10
0
δ Deuterium (‰)
0
1
2
3
10
15
20
25
Tritium (TU)

GROUNDWATER FLOW IN THE VADOSE CHALK, NEGEV, ISRAEL

Calculated Infiltration Velocity

* From saturated zone information, using tritium and contamination in groundwater: >1500 and 2400 mm/yr, respectively

* From vadose zone information, using tritium and bromide in the matrix: 30 and 110 mm/yr, respectively

Conclusion

Fracture flow accounts for the two orders of magnitude difference.

Isotopic Indications for Fracture-Controlled Flow in the Saturated Zone

(a) Presence of contamination and tritium in deep groundwater

Alternative: Tritium and contamination do not move vertically via the vadose zone but laterally from dissecting streams.

(b) Resemblance of O-18 and D in precipitation and groundwater

Alternative: Similarity results from focused, isotopically light recharge through porous riverbeds.

Isotopic Indications for Fracture-Controlled Flow in the Saturated Zone

(c) Heterogeneity of isotopic composition

Alternative: No lateral flow (i.e. no contamination risk).

(d) No evolution along apparent flow paths

Alternative: No lateral flow (i.e. no contamination risk).

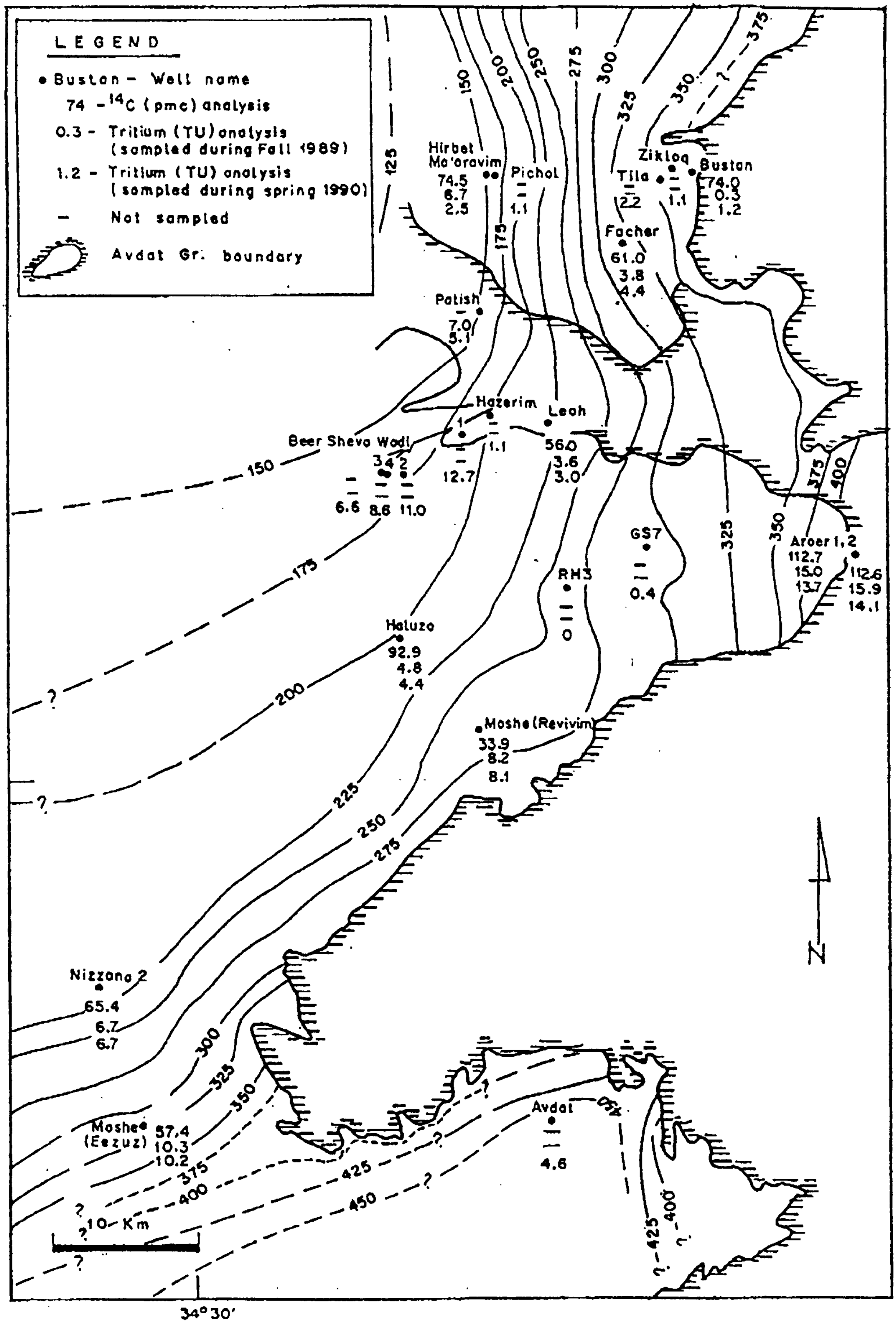
Isotopic Indications for Fracture-Controlled Flow in the Saturated Zone

(c) Heterogeneity of isotopic composition

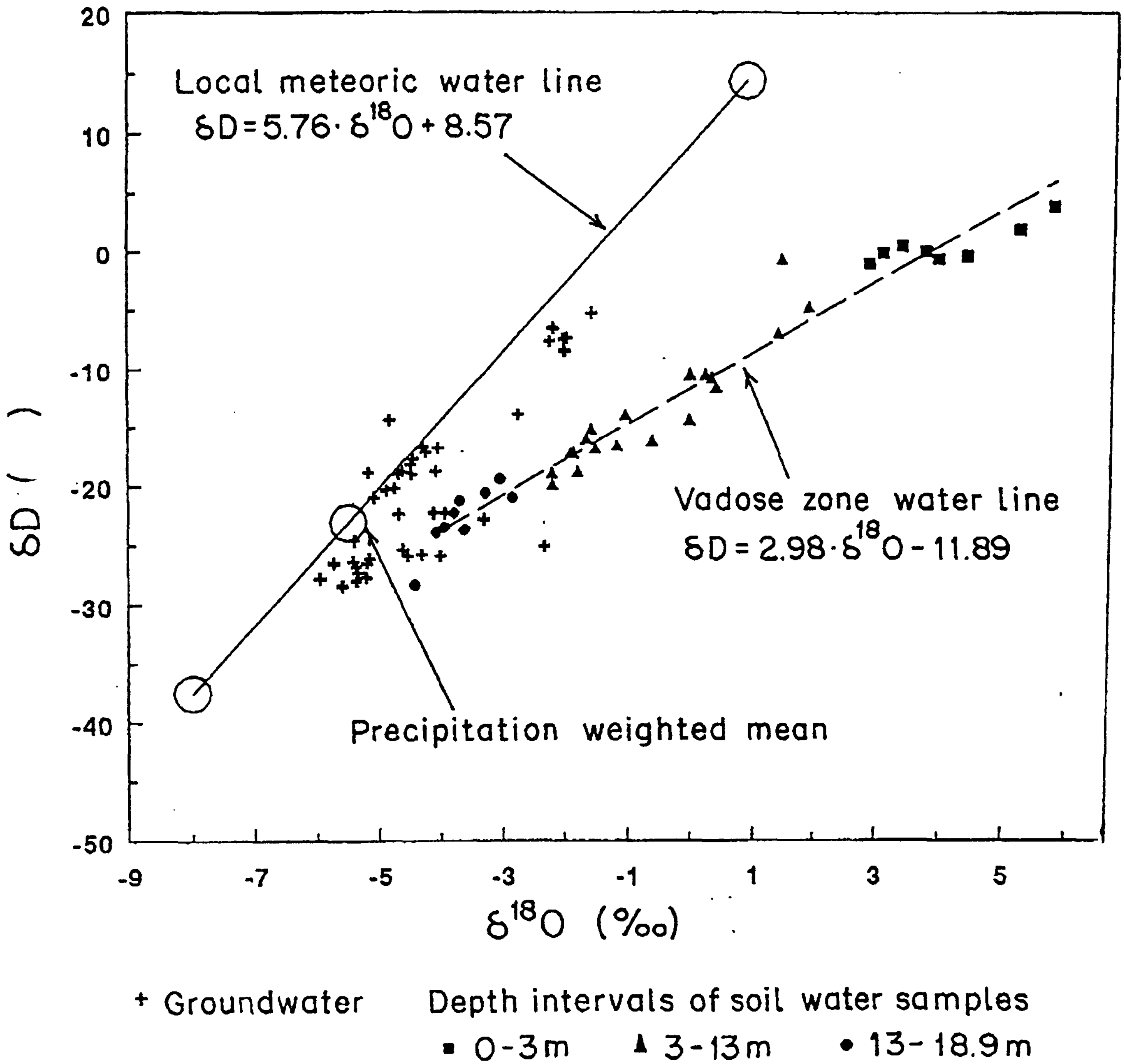
Alternative: No lateral flow (i.e. no contamination risk).

(d) No evolution along apparent flow paths

Alternative: No lateral flow (i.e. no contamination risk).



LEGEND
• Buston - Well name
74 - ^{14}C (pmc) analysis
0.3 - Tritium (TU) analysis (sampled during Fall 1989)
1.2 - Tritium (TU) analysis (sampled during spring 1990)
— Not sampled
Avdat Gr. boundary
Hirbet Ma'oravim
74.5
6.7
2.5
Pichol
1.1
Zikloq
Tila
2.2
1.1
Buston
74.0
0.3
1.2
Facher
61.0
3.8
4.4
Patish
7.0
5.1
Hazerim
1.1
Leah
56.0
3.6
3.0
Beer Shevo Wadi
12.7
6.6
8.6
11.0
GS7
0.4
RH3
0
Aroer 1,2
112.7
15.0
13.7
112.6
15.9
14.1
Haluza
92.9
4.8
4.4
Moshe (Revivim)
33.9
8.2
8.1
Nizzana 2
65.4
6.7
6.7
Moshe (Eezuz)
57.4
10.3
10.2
Avdat
4.6
10 Km
31°00'
34°30'
N



Local meteoric water line
δD=5.76·δ18O+8.57
Vadose zone water line
δD=2.98·δ18O-11.89
Precipitation weighted mean
20
10
0
-10
-20
-30
-40
-50
-9
-7
-5
-3
-1
1
3
5
δD ( )
δ18O (‰)
+ Groundwater
Depth intervals of soil water samples
▪ 0-3m
▲ 3-13m
• 13-18.9m

Isotopic Indications for Fracture-Controlled Flow in the Vadose Zone

(a) Isotopic profiles in the vadose zone

Alternative: Tritium spikes result from sample contamination. Stable isotope compositions are affected by diffusion.

(b) Mineralization

Alternative: Secondary minerals are flow barriers.